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ATLAS Overview

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Abstract. ATLAS STATUS REPORT of the construction work, including for the first time a report on the ongoing underground installation work. The status of all major subsystems is being presented. Particular emphasis is given to ongoing work for final assembly and integration ready for installation in the cavern.

PACS:

1 Introduction

The ATLAS Collaboration is progressing steadily as planned in the construction of its general-purpose detector to exploit the rich discovery potential of the LHC. The detector has been under construction for more than six years, and is now more than 60% complete in terms of expenditures. The Collaboration currently consists of 151 Institutions from 35 countries with about 1610 scientific authors (including students).

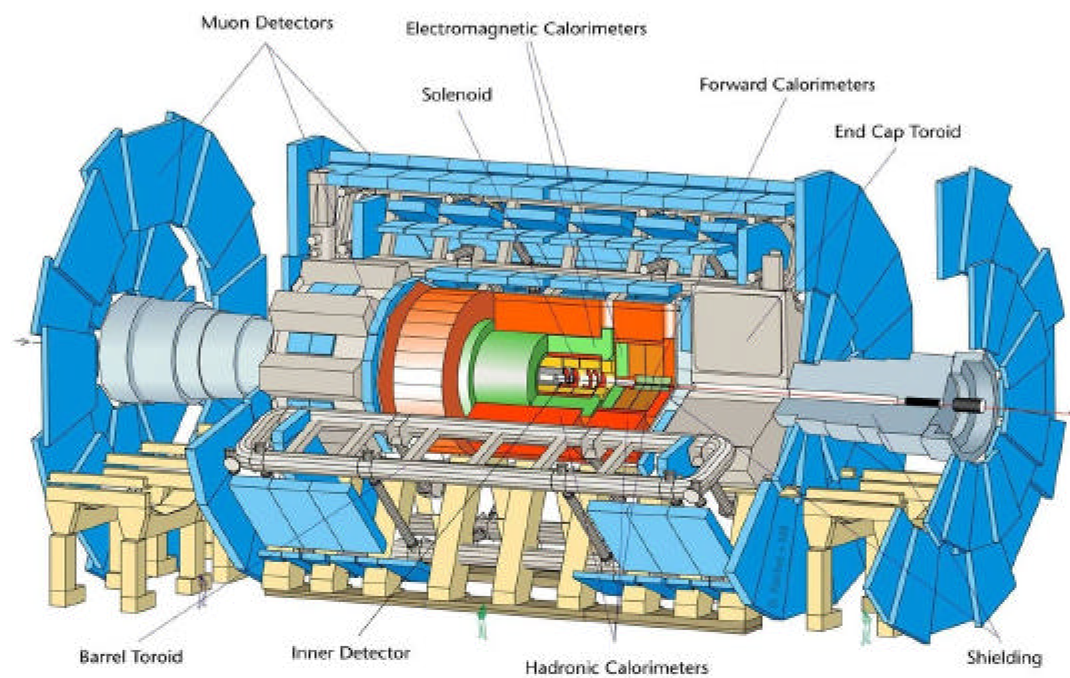

Fig. 1. ATLAS Detector

It can be briefly recalled here that the detector concept is based on a superconducting Magnet System with a central solenoid around the Inner Detector for tracking and large air-core toroidal magnets for the Muon Spectrometer. Between the two are the Liquid Argon (LAr) and Tile Calorimeters. A hierarchical Trigger and Data Acquisition System (DAQ) will provide the data for the Collaboration-wide computing and physics analysis activities.

The report presented at the Symposium covers the main progress and concerns in all these areas. The overall status of the ATLAS project is reviewed regularly by the LHC committee (LHCC), which also conducts an annual Comprehensive Review.

Particular emphasis was given over the past half year to the careful planning for the installation activities at LHC Point 1, which has now started. Mid-April 2003 part of the underground experimental area (UX15) has been delivered by the civil engineering to ATLAS.

Fig. 2. TX1S Shielding installation in the underground cavern

First, the low beta shielding TX1S (400 tons of material) has been installed on both sides (see Figure 2). This work is now continuing with the installation of all infrastructure components (metallic structures, cranes, air ventilation system, electrical system,…).
This presentation has been organized in a way to show, with the help of virtual reality simulations, the various phases of the installation work, the associated schedule and the major problems to be faced along this way.
Today the main installation schedule, which consists of about 2000 individual work packages, shows the detector in its initial configuration (some components will be staged for later installation), ready for physics in December 2006, with about six months of global commissioning time foreseen, starting summer 2006. This plan is being developed in great detail including all logistics and resource matters.

One of the most critical issues is the installation of the Barrel Toroid, both in terms of complexity and scheduling risks. In order to coordinate the ATLAS installation activities, an 'Experi-

mental Area Management' organization has been set up, involving efforts from several CERN divisions and sectors, and has now been in operation for six months with good experience. The progress of the civil engineering work on the surface and in the experimental cavern was good over the past year. The installation phase of the ATLAS detector therefore started mid-April 2003, with the infrastructure components (phase 1), and it will be followed in mid-November 2003 by the start of phase 2 (see Figure 3) with the bedplates, the feet and the first Barrel Toroid (BT) coils. A new activity, the planning of the commissioning, has also been initiated.
The completion plan for the staged initial detector configuration, taking into account the Cost to Completion (CtC) for the parts which are not covered as deliverables, including the Commissioning & Integration (C&I) pre-operation costs as well as the available resources, was presented and approved at the October 2002 RRB (CERN-RRB-2002-114). Since then, the detector construction and integration is proceeding within this framework.

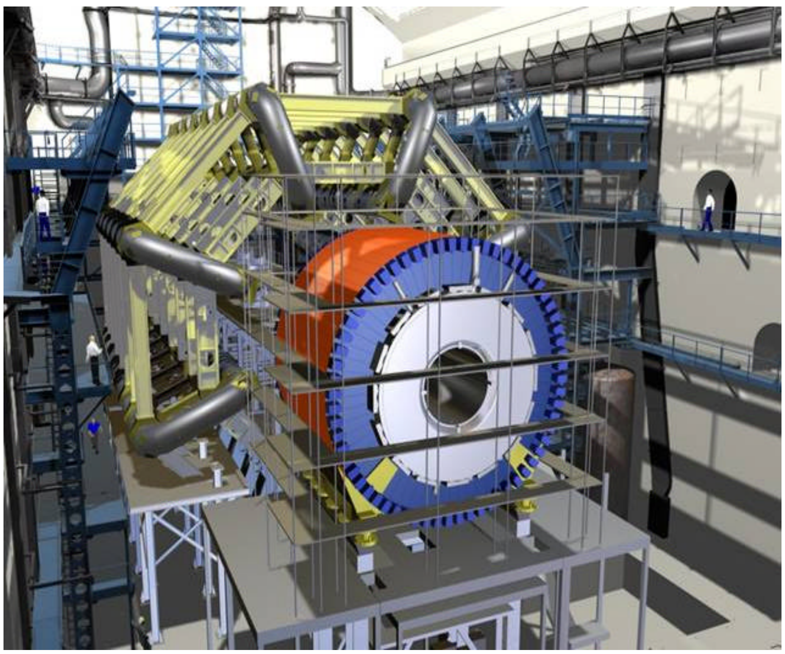

Fig. 3. Engineering simulation of one of the various installation Phases. Here the end of Phase 2 is represented, when the Barrel Toroid and the Barrel Calorimeter will have been installed in position (October 2004).

2 Magnet System

The ATLAS magnet system is the largest Common Project component. The toroids and the central solenoid are serviced by common cryogenics, power, and control systems, for which many components have already been delivered or are in construction. As a first system the Helium refrigerators are being installed at the LHC point 1. All the ATLAS magnets also share the same large test-station facility in CERN Hall 180, which has been fully operational since the prototype barrel toroid B0 coil tests in 2001.

The BT assembly is proceeding at CERN (see Figure 4) according to the planning. All of the superconductor has been delivered and completed in double pancakes. Seven of the eight coil casings are fabricated and are at CERN. Six of the eight vacuum vessels are already accepted, and completion is foreseen for summer 2003. All other components of the cold mass are also in production and the first stage integration work is proceeding well, with coil number four (May 2003) entering the impregnation phase. There is a major delay in the delivery of the heat shields needed for the second integration step, the assembly of the cold masses into the vacuum vessels. This determines now the critical path, which implies that the first BT coil will be tested in summer 2003 only, instead of March 2003. The industrial contract for the cold-mass integration had to be cancelled at the beginning of 2002 because of over-cost claims and delays (In the meantime the firm was declared insolvent). The work had to be rearranged and the execution is now proceeding at CERN, involving experts from a firm and from ATLAS magnets labs, with collaboration manpower in addition. The BT schedule is on the critical path, in particular the second integration step of the coils. The last two coils will be available for installation just in time, not respecting the four-months "float period" which ATLAS requires as schedule contingency for each component. The plan is to complete production of components, proceed with the coil integration and explore possible schedule recovery based on the experience with the first coil, finalize the detailed planning for the BT installation and fabricate all tooling needed for this.

Fig. 4. Barrel Toroid assembly at CERN (bdg. 180).

Also the construction of the Endcap Toroids (ECT) is proceeding according to the plans. The superconductor production is finished. The vacuum vessels for the two end-caps have been completed, delivered to CERN and vacuum tested. The integration work with super-insulation and heat shields is far advanced. The coil winding and cold-mass assembly is now proceeding well after corrective actions were taken when ATLAS suffered earlier delays of about one year due to a factory take-over. Eight out of 16 coils have been wound, and the first one has been successfully impregnated. A very strict follow-up at the firm for the coil winding and cold mass fabrication is now in place. The plan is to proceed with the cold mass fabrication. The anticipated delivery date for the first of the two ECTs is end 2003.

The Central Solenoid is completed and was accepted at CERN in October 2001. Since then the cryogenics proximity services have successfully undergone a complete test, and are now also ready for installation. Its integration into the LAr barrel cryostat is foreseen in October 2003.

3 Calorimeters

The second major element to be installed underground, in spring 2004, is the calorimeter system. First the barrel Tile Calorimeter, then the barrel LAr followed by the two end-caps. The construction work on both calorimeters is proceeding well and according to planning.

Concerning the Tile Calorimeter, the module construction and instrumentation with optical components (scintillators and fibres) is finished for all three cylinders (the barrel and the two extended barrels). The pre-assembly of the cylinders has started at CERN, and the first extended barrel cylinder has been completed in April 2003 (see Figure 5). All photomultipliers have been delivered and tested. The electronics components are also in the production phase, and their assembly into the 'drawer' system, housing all on-detector electronics circuits, is ongoing. However, some delays have occurred in this activity because of two component failures on the digitizer boards that need corrective actions. In the meantime, the assembly of the drawers will proceed without these boards, which can be added later. The plan is to continue the pre-assembly of the tile calorimeter cylinders (next is the barrel one) in order to gain time later for the final assembly in the cavern. A sample of modules is undergoing beam calibrations; the community is preparing a combined beam test with the LAr Electromagnetic Calorimeter (EM), this major operation is scheduled for 2004.

Fig. 5. First Tile Calorimeter cylinder fully pre-assembled on the surface and ready for installation underground (April 2003).

All sub-systems of the LAr Calorimeter are well advanced in, or have already finished, their construction phase. Since several months the main emphasis has shifted to the assembly and integration phase. Important large-scale test beam campaigns are foreseen during 2003 and 2004 with the various combined calorimeter sub-systems.

The barrel LAr EM calorimeter and the pre-samplers are approaching completion of the series production, all the 32 modules are stacked, and 29 cold-tested. The first half-barrel cylinder (with 16 modules) has been assembled and successfully inserted into the cryostat (see Figure 6). For the end-cap EM calorimeter, nine of the 16 modules have been stacked, and eight cold-tested. Completion is currently scheduled for March 2004. The pre-sampler series fabrication is also well underway and is matching the schedules for both the barrel and the end-caps. The schedule risks for the second end-cap are partially due to manpower shortage. The plan is to continue and complete the series production, as well as assemble and integrate modules into the second half-barrel cylinder (fall 2003) and end-cap wheels for insertion into the cryostats.

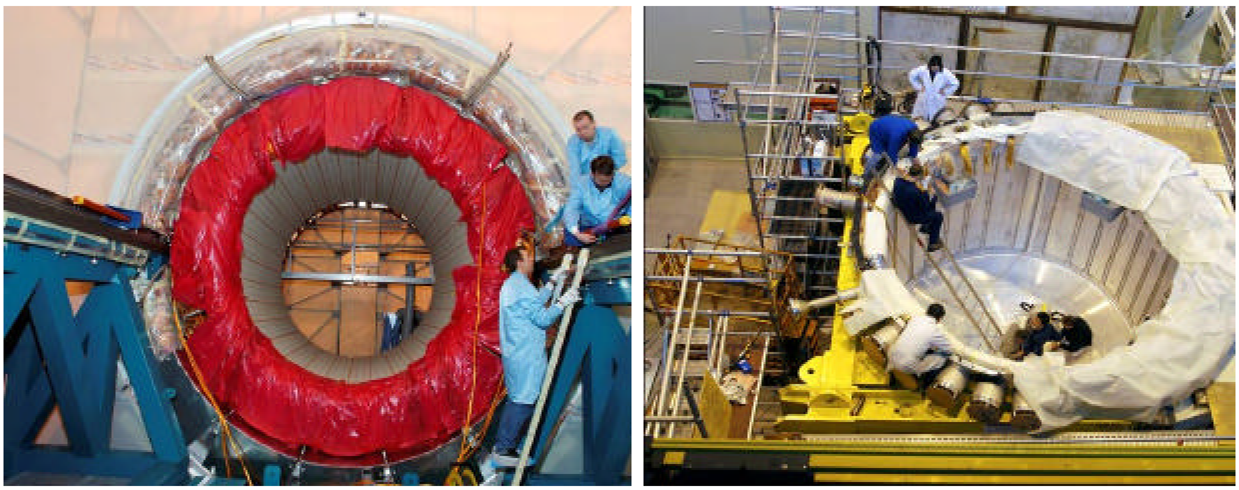

Fig. 6. a) First EM barrel LAr half wheel inserted in its cryostat. b) End-cap cryostat C during the signal feed-through installation.

The LAr Hadronic End-Cap Calorimeter (HEC) series production is complete, with all 134 modules (including six spares) stacked, and most of them already cold-tested. In the first integration step the modules are assembled into 'wheels', and three of the four wheels have already been assembled and are ready for insertion into the two end-cap cryostats. The strategy is to continue the assembly sequence of wheels in order to accommodate delays in the EM end-cap fabrication. This will require a special storage support stand.

The three Forward Calorimeter (FCAL) modules for the first side of ATLAS were cold-tested and are ready for a beam calibration run in June 2003. The assembly of the modules for the second side is complete as well, and all are expected to be at CERN by mid-May 2003 for the final integration work.

The barrel cryostat integration work at CERN has progressed well and the first EM half-barrel cylinder was inserted recently. The first of the two end-cap cryostats has been delivered to CERN, and after delays because of a necessary repair, it has now been fitted with all feed-throughs and is almost ready to receive the EM and HEC wheels. The second end-cap cryostat is expected to arrive at CERN in May 2003, close to the critical path. All the feed-throughs have been delivered to CERN. There is also good progress on the cryogenics plant, with most components ordered and under fabrication.

There is steady progress on the LAr electronics. Radiation tolerant versions of the front-end modules have been developed, and design reviews for all units required for calibration and

data acquisition were held. Prototype modules for the radiation tolerant FE boards were produced and successfully operated in early 2003, as were other radiation tolerant boards for calibrations and controls. The back-end electronics, which consists mainly of the Read Out Driver (ROD) system, is also proceeding on schedule, with prototypes and design reviews passed for several components.
The availability of radiation tolerant negative voltage regulators has delayed the schedule for the front-end electronics, and represents a remaining risk. Several chips still have to be produced in the DMILL technology, which is expected to be terminated. The plan is to continue with the preparation and tests for the Production Readiness Review for the full FE boards, to finalize the developments for the back-end electronics and to start the final system test by end 2003.

4 Muon Spectrometer

Once the Barrel Calorimeters are in place inside the Barrel Toroid and their services and cables are routed, the time will come to start the installation of the Muon system (January 2005). First the barrel chambers will be installed, in parallel to the End-Cap Calorimeters. After that the Muons wheels will be installed.

The Muon Spectrometer is instrumented with precision chambers for momentum measurements, complemented with fast chambers for triggering. All chamber sub-systems are in series construction. System aspects, such as the crucial alignment monitoring and calibration, are being studied in a large test beam set up at the CERN SPS (see Figure 7).

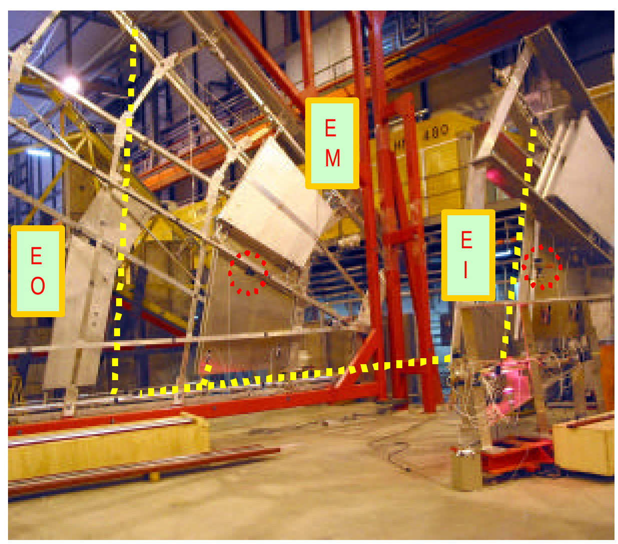

Fig. 7. a) First MDT+RPCS assembly. b) Test beam test stand in the SPS H8 beam line.

The Monitored Drift Tube (MDT) chambers from 13 production sites are following the planned construction schedule, with more than 50% of the bare chambers assembled by now, and almost 20% fully integrated with their services. A corrective action was necessary on early production chambers because of gas leaks that were observed in the on-chamber gas tubelets, due to corrosion from cleaning agents. The MDT electronics has passed pre-series tests, and the final production starts in May 2003. Cathode Strip Chambers (CSCs) are used in the innermost end-cap region because of the high radiation fluxes. Their component construction has been launched and has passed the 50% mark, and assembly of the chambers has also started.

The Trigger Chambers are also well advanced, and in production. The barrel part is equipped with Resistive Plate Chambers (RPCs). After two pre-series, full production is now ongoing with components ready for more than 20% of the chambers, and with 15% of the RPC units assembled. Further improvements in QC steps are still investigated to lower the rate of chambers that need interventions before final acceptance. A sample of the series chambers is being submitted to a final radiation test qualification in the dedicated X5 beam facility at CERN, repeating earlier successful tests. The end-cap regions are instrumented with Thin Gap Chambers (TGCs) which are able to cope with high rates. The TGC series fabrication is well advanced, with more than 70% of all material prepared and machined. The first two sites have produced each more than 55% of their chambers. The third site has recently started, and has already produced about 30%. All on-chamber TGC electronics have been fabricated and tested successfully.

The Muon Spectrometer Integration and its system aspects are now taking major attention from the Collaboration. A large-scale test facility for alignment, mechanics, and many other system aspects has been built at the SPS H8 beam and is now fully operational. Many of the important performance aspects have been validated. The design work for the large mechanical end-cap chamber support structures has been finalized, and the procurement launched. Furthermore, the design has been completed for the services routing from the inner detector layers through the muon spectrometer. Progress has also been achieved with the issue of storage and integration space. Large batches of chambers are now arriving regularly at CERN. During 2003 a new integration facility at CERN is starting with the purpose to integrate MDT and RPC chambers in a unique package ready for assembly underground. Each pre-assembly will need to be fully qualified and tested using cosmic muons. All services and electronics will need to be tested and qualified. Production of the necessary gas system is starting. Major worries are related to the quality of the cleaning of this system, to avoid Silicon contamination which might cause aging effects.

5 Inner Detector

The Inner Detector (ID) consists of three concentric sub-systems, namely (from inside out), the pixel detector, the silicon detector (SCT) and the transition radiation straw tracker (TRT). The component fabrication is ongoing for all of them. By now also module production has started. An important effort will be the integration of the three sub-systems, and their common ID infrastructure and services, for which preparations are advancing well.
From a point of view of installation, four assemblies will be moved down as one unique piece : the barrel structure (TRT +SCT), two end-caps (TRT + SCT), the pixel detector integrated around the Be beam pipe. All the four mounts will be assembled, tested and commissioned on the surface, in the large clean room (SR1) just completed. Large-scale cooling tests have been pursued successfully. The final layout of the services routing has progressed satisfactorily, and will be checked on a second-generation full-scale mock-up.
Very important now are the completion of the cooling tests and bringing into operation the clean room facility which will receive the first ID detector elements at CERN during this year.

5.1 Pixel Detector

The pixel sensor series fabrication has been launched and is now at the 25% completion level. The FE electronics in radiation hard deep sub-micron (DSM) technology is proceeding well even though yield variations observed are still being investigated. Final prototype modules were irradiated and tested successfully. All high-tech light-weight mechanics support parts are well advanced and passed final design reviews. The issue now is to gear up module series production and perform large-scale system tests.

5.2 Silicon Detector

The SCT sensor fabrication is very close to completion, with more than 90% delivered and accepted. The FE electronics fabrication is underway and more than 80% complete, however low yield and the announcement of the closure of the DMILL process at the foundry are a serious concern for the remaining chips. The barrel module construction has been launched at the four sites, and around 300 of the 2000 barrel modules have been produced. The module and support structures are under construction for the barrel (see Figure 8). The end-cap module production was delayed because of excess noise problems observed in system tests, requiring a new hybrid design. New end-cap prototype modules have reached acceptable performance, and the sites are now preparing for series production. The off-detector parts are progressing according to schedule.

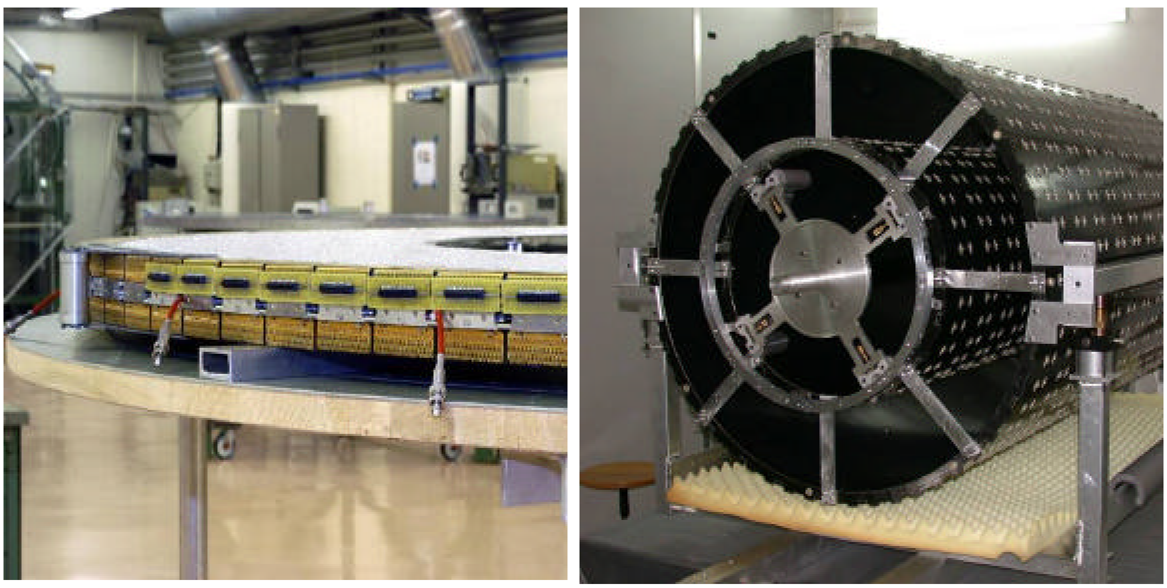

Fig. 8. a) First TRT 8 wheel plan assembly. b) SCT barrel support structures.

Here the main issue is to move to steady module production for the barrel, and qualify module assembly sites for the end-cap SCT. Assembly of the first barrel SCT cylinder is on the critical path.

5.3 Transition Radiation Tracker

The straw production and reinforcement have been completed. The end-cap wheel assembly has started at the two sites, and the first four modules were delivered to CERN (see Figure 8), albeit with delays in particular due to an excessive failure rate in a key component (the Web circuits). This issue is being followed-up with highest priority while partial assembly of the wheels continues. The mechanical construction of the barrel TRT modules is close to comple-

tion, and wire stringing is more than 50% complete. The optimization for a new baseline gas mixture has been vigorously pursued and concluded. A new baseline gas mixture has been adopted as an answer to the aging problems found in the last few years. The FE electronics developments have been successfully completed, but a serious concern are the FE ASIC chips, the ADSBLR, which are subject to the same uncertainties in the DMILL process at the foundry as mentioned above for the SCT FE chips.
For this system the key issues are the availability of the radiation-hard process for the ADSBLR FE chip, the schedule for the end-cap TRT wheel production and assembly, as well as the coverage of the over-costs related to the initial staged TRT configuration. In autumn 2003 the barrel module assembly shall be completed and barrel integration at CERN will start. The end-cap wheel production is on the critical path and will need optimization.

6 Trigger and DAQ System

The level-1 trigger system activities are progressing well and consistently with the plans from the Technical Design Report (TDR), with successful ASIC developments and full-functionality prototype modules for the components from the three sub-systems (calorimeter, muon and central trigger logic). Major emphasis has been put on extended system tests ('slice-tests' of the detector and electronics) to confirm the final design. This system is now moving into the construction phase.

For the High Level Trigger (HLT) and DAQ system (see Figure 9), integrated prototypes have been developed to demonstrate functionality and performance scaling, in order to guide the design for the TDR. Architectural choices have been made recently, which will allow work to proceed, but leave enough flexibility to benefit from future developments in information technology. In these considerations the scalability of the HLT/DAQ system is also particularly important for staging needs during the initial running of ATLAS. Further areas of focused work where good progress has been achieved are the DCS and the Detector Interface Group (DIG), standardizing the interfacing of DAQ with the various detector read-out electronics.The HLT/DAQ/DCS TDR is due for submission to the LHCC by the end of June 2003. Here the plans are to exploit the integrated HLT/DAQ prototypes and finalize the system design for the TDR. Implementation of prototypes at test beams under real-life test conditions with detector systems is being prepared.

7 Computing

The running of the first Data Challenges (DCs) focused on broad and coherent computing and software activities. This required that most of the key software components worked together. DC1 provided a very high statistics-simulated event sample for the HLT/DAQ TDR, consisting of more than ten million fully simulated events. In its final phase DC1 successfully spanned over 56 Institutes in 20 countries all over the Collaboration. GRID software was already deployed in several instances. DCs will continue approximately annually, and will be embedded naturally into the framework of the CERN LHC Computing Grid Project (LCG), as soon as possible. ATLAS is a very active partner in the LCG, with significant effort committed to this project. Further major activities cover the development of the ATHENA framework which acts as a backbone for the whole software chain, and the validation of the new GEANT4 simulation software.

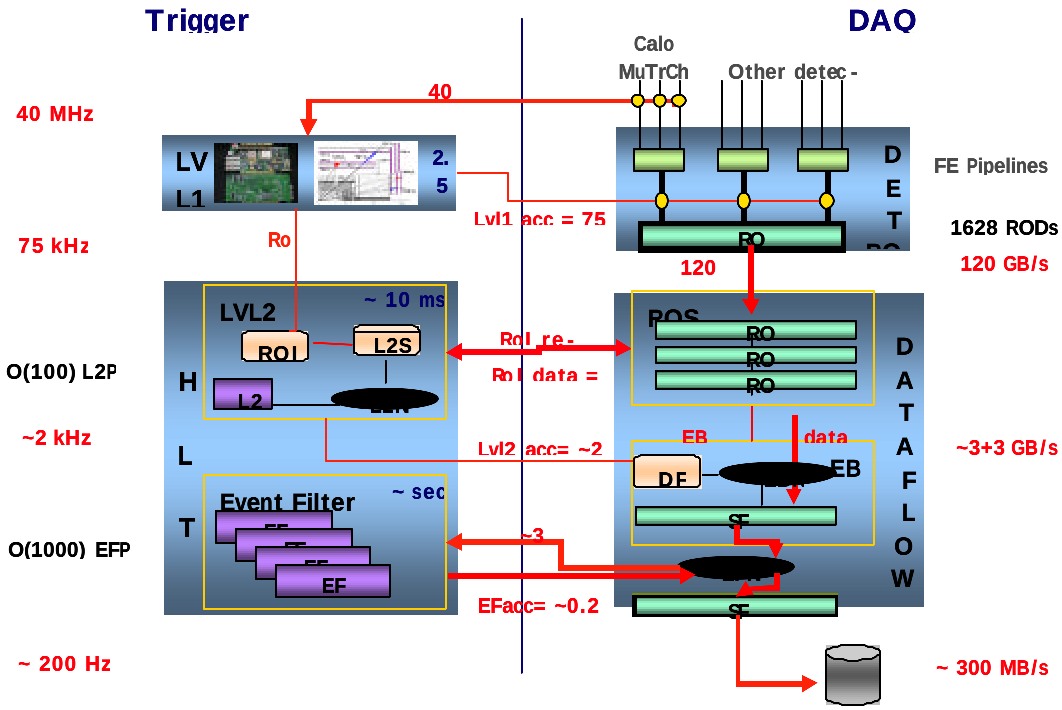

Fig. 9. Trigger and Data Acquisition block diagram.

A real concern is the timely availability of crucial software packages and the shortage of experiment-specific manpower for software and computing support tasks. Our plans are to consolidate and develop the software suite for ATLAS in a Collaboration-wide computing approach, in full coherence with LCG and to deploy more and more GRID middleware as soon as possible for the DC activity.

8 Summary

At the ATLAS RRB meeting in October 2002 a completion plan for the initial detector has been discussed and approved. This plan takes into account the Cost to Completion (CtC) for the parts which are not covered as deliverables, and includes the Commissioning and Integration (C&I) pre-operation costs until 2006. It fits into the framework of the available resources agreed to at the RRB by the Funding Agencies. The detector planning, construction and integration have since proceeded within this framework.

The components construction work is well advanced and has for many systems passed the 50% milestone. Some systems, like calorimeters, are advanced even further or near to completion.
All parts are now converging to CERN where they get integrated in larger assemblies, tested and commissioned on the surface. Many halls at CERN are hosting such activities.
Since April, the ATLAS installation underground has started. This new activity is complex and challenging. It is planned in great detail and will last over the next three years.
In summer 2003, after the TDR is submitted, also the high-level trigger and DAQ system will enter the construction phase.

The Collaboration is more than ever well motivated and focused on the successful completion and commissioning of the initial detector. ATLAS will be ready in time for the first LHC beams.

It is well understood that the funding situation is expected to evolve with time. In many cases Funding Agencies have confirmed their best efforts to secure additional resources to the ones they were already able to commit. This would then allow the ATLAS Collaboration to gradually improve the expected performance of its initial detector, thereby becoming capable to exploit more fully the great LHC physics opportunities, and being ready for the future high-luminosity operation of the LHC.